

CLAIMS

- 1 1. A method for analyzing an image, comprising:
2 constructing a graph to represent an object
3 appearing in the image;
4 generating a string of symbols corresponding to the
5 graph; and
6 processing the string so as to classify the object.
- 1 2. A method according to claim 1, wherein generating
2 the string comprises generating first and second strings
3 to represent first and second graphs, respectively, so
4 that the first and second strings are identical if and
5 only if the first and second graphs are isomorphic.
- 1 3. A method according to claim 2, wherein the graphs
2 comprise vertices, and wherein constructing the graph
3 comprises constructing the first and second graphs so
4 that the vertices of each of the graphs are arranged in a
5 specified spatial relation, and wherein generating the
6 first and second strings comprises constructing the
7 strings so as to reflect the spatial relation of the
8 vertices.
- 1 4. A method according to claim 3, wherein constructing
2 the graph comprises assigning the vertices to represent
3 respective portions of a contour of a shape of the object
4 in the image, and arranging the vertices in the specified
5 spatial relation responsive to relative positions in the
6 image of the respective portions of the contour.
- 1 5. A method according to claim 4, wherein assigning the
2 vertices comprises positioning Cartesian coordinate axes
3 relative to the contour and determining the relative
4 positions of the portions of the contour with respect to

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5 the axes, and wherein arranging the vertices comprises
6 positioning the vertices so as to preserve up/down and
7 left/right relations of the positions of the portions of
8 the contour.

1 6. A method according to claim 1, wherein constructing
2 the graph comprises dividing a contour of a shape of the
3 object in the image into multiple portions, and assigning
4 vertices of the graph respectively to represent the
5 portions of the contour.

1 7. A method according to claim 6, wherein dividing the
2 contour comprises positioning Cartesian coordinate axes
3 relative to the contour at a plurality of different
4 orientation angles, and finding the portions of the
5 contour at each of the angles, and

6 wherein constructing the graph comprises
7 constructing a plurality of respective graphs in which
8 the vertices represent the portions of the contour at the
9 different orientation angles, and

10 wherein generating and processing the string
11 comprise generating and processing a plurality of strings
12 corresponding to the respective graphs so as to classify
13 the shape.

1 8. A method according to claim 6, wherein constructing
2 the graph comprises constructing a sequence of graphs
3 that correspond to successively simplified versions of
4 the contour and accordingly comprise successively
5 decreasing numbers of the vertices, and

6 wherein generating and processing the string
7 comprise generating and processing a plurality of strings
8 corresponding to the graphs in the sequence so as to
9 classify the shape.

1 9. A method according to claim 8, wherein processing
2 the plurality of the strings comprises arranging the
3 strings as elements of a first vector, indexed according
4 to the numbers of the vertices in the corresponding
5 graphs, and computing a measure of distance between the
6 first vector and a second vector, representing a
7 reference contour and indexed in like manner to the first
8 vector, so as to determine a similarity of the shape to
9 the reference contour.

1 10. A method according to claim 1, wherein the graph
2 comprises vertices, and wherein generating the string of
3 symbols comprises performing a depth-first search over
4 the vertices of the graph, and adding one or more symbols
5 to the string for each edge encountered in the search.

1 11. A method according to claim 1, wherein processing
2 the string comprises comparing the string to a reference
3 string representing a reference object so as to assess a
4 similarity of the object to the reference object.

1 12. A method according to claim 11, wherein comparing
2 the string comprises computing a string distance between
3 the string and the reference string, so as to calculate a
4 measure of shape difference between the object and the
5 reference object.

1 13. Apparatus for analyzing an image, comprising an
2 image processor, arranged to construct a graph to
3 represent an object appearing in the image, to generate a
4 string of symbols corresponding to the graph, and to
5 process the string so as to classify the object.

1 14. Apparatus according to claim 13, wherein the
2 processor is arranged to generate first and second

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3 strings to represent first and second graphs,
4 respectively, so that the first and second strings are
5 identical if and only if the first and second graphs are
6 isomorphic.

1 15. Apparatus according to claim 14, wherein the graphs
2 comprise vertices, and wherein the processor is arranged
3 to construct the first and second graphs so that the
4 vertices of each of the graphs are arranged in a
5 specified spatial relation, and to generate the first and
6 second strings so as to reflect the spatial relation of
7 the vertices.

1 16. Apparatus according to claim 15, wherein the
2 processor is adapted to assign the vertices to represent
3 respective portions of a contour of a shape of the object
4 in the image, and to arrange the vertices in the
5 specified spatial relation responsive to relative
6 positions in the image of the respective portions of the
7 contour.

1 17. Apparatus according to claim 16, wherein the
2 processor is arranged to position Cartesian coordinate
3 axes relative to the contour and to determine the
4 relative positions of the portions of the contour with
5 respect to the axes, and to position the vertices so as
6 to preserve up/down and left/right relations of the
7 positions of the portions of the contour.

1 18. Apparatus according to claim 13, wherein the
2 processor is arranged to divide a contour of a shape of
3 the object in the image into multiple portions, and to
4 assign vertices of the graph respectively to represent
5 the portions of the contour.

1 19. Apparatus according to claim 18, wherein the
2 processor is arranged to position Cartesian coordinate
3 axes relative to the contour at a plurality of different
4 orientation angles and to find the portions of the
5 contour at each of the angles, and is further arranged to
6 construct a plurality of respective graphs in which the
7 vertices represent the portions of the contour at the
8 different orientation angles, so as to generate and
9 process a plurality of strings corresponding to the
10 respective graphs for use in classifying the shape.

1 20. Apparatus according to claim 18, wherein the
2 processor is arranged to construct a sequence of graphs
3 that correspond to successively simplified versions of
4 the contour and accordingly comprise successively
5 decreasing numbers of the vertices, and to generate and
6 process a plurality of strings corresponding to the
7 graphs in the sequence for use in classifying the shape.

1 21. Apparatus according to claim 20, wherein the
2 processor is adapted to arrange the strings as elements
3 of a first vector, indexed according to the numbers of
4 the vertices in the corresponding graphs, and to compute
5 a measure of distance between the first vector and a
6 second vector, representing a reference contour and
7 indexed in like manner to the first vector, so as to
8 determine a similarity of the shape to the reference
9 contour.

1 22. Apparatus according to claim 13, wherein the graph
2 comprises vertices, and wherein the processor is arranged
3 to generate the string of symbols by performing a
4 depth-first search over the vertices of the graph, and

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5 adding one or more symbols to the string for each edge
6 encountered in the search.

1 23. Apparatus according to claim 13, wherein the
2 processor is arranged to compare the string to a
3 reference string representing a reference object so as to
4 assess a similarity of the object to the reference
5 object.

1 24. Apparatus according to claim 23, wherein the
2 processor is arranged to compare the string by computing
3 a string distance between the string and the reference
4 string, so as to calculate a measure of shape difference
5 between the object and the reference object.

1 25. A computer software product, comprising a
2 computer-readable medium in which program instructions
3 are stored, which instructions, when read by a computer,
4 cause the computer to construct a graph to represent an
5 object appearing in an image, to generate a string of
6 symbols corresponding to the graph, and to process the
7 string so as to classify the object.

1 26. A product according to claim 25, wherein the
2 instructions cause the computer to generate first and
3 second strings to represent first and second graphs,
4 respectively, so that the first and second strings are
5 identical if and only if the first and second graphs are
6 isomorphic.

1 27. A product according to claim 26, wherein the graphs
2 comprise vertices, and wherein the instructions cause the
3 computer to construct the first and second graphs so that
4 the vertices of each of the graphs are arranged in a
5 specified spatial relation, and to generate the first and

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6 second strings so as to reflect the spatial relation of
7 the vertices.

1 28. A product according to claim 27, wherein the
2 instructions cause the computer to assign the vertices to
3 represent respective portions of a contour of a shape of
4 the object in the image, and to arrange the vertices in
5 the specified spatial relation responsive to relative
6 positions in the image of the respective portions of the
7 contour.

1 29. A product according to claim 28, wherein the
2 instructions cause the computer to position Cartesian
3 coordinate axes relative to the contour and to determine
4 the relative positions of the portions of the contour
5 with respect to the axes, and to position the vertices so
6 as to preserve up/down and left/right relations of the
7 positions of the portions of the contour.

1 30. A product according to claim 25, wherein the
2 instructions cause the computer to divide a contour of a
3 shape of the object in the image into multiple portions,
4 and to assign vertices of the graph respectively to
5 represent the portions of the contour.

1 31. A product according to claim 30, wherein the
2 instructions cause the computer to position Cartesian
3 coordinate axes relative to the contour at a plurality of
4 different orientation angles and to find the portions of
5 the contour at each of the angles, and further cause the
6 computer to construct a plurality of respective graphs in
7 which the vertices represent the portions of the contour
8 at the different orientation angles, so as to generate

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9 and process a plurality of strings corresponding to the
10 respective graphs for use in classifying the shape.

1 32. A product according to claim 30, wherein the
2 instructions cause the computer to construct a sequence
3 of graphs that correspond to successively simplified
4 versions of the contour and accordingly comprise
5 successively decreasing numbers of the vertices, and to
6 generate and process a plurality of strings corresponding
7 to the graphs in the sequence for use in classifying the
8 shape.

1 33. A product according to claim 32, wherein the
2 instructions cause the computer to arrange the strings as
3 elements of a first vector, indexed according to the
4 numbers of the vertices in the corresponding graphs, and
5 to compute a measure of distance between the first vector
6 and a second vector, representing a reference contour and
7 indexed in like manner to the first vector, so as to
8 determine a similarity of the shape to the reference
9 contour.

1 34. A product according to claim 25, wherein the graph
2 comprises vertices, and wherein the instructions cause
3 the computer to generate the string of symbols by
4 performing a depth-first search over the vertices of the
5 graph, and adding one or more symbols to the string for
6 each edge encountered in the search.

1 35. A product according to claim 25, wherein the
2 instructions cause the computer to compare the string to
3 a reference string representing a reference object so as
4 to assess a similarity of the object to the reference
5 object.

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1 36. A product according to claim 35, wherein the
2 instructions cause the computer to compare the string by
3 computing a string distance between the string and the
4 reference string, so as to calculate a measure of shape
5 difference between the object and the reference object .